UNCLASSIFIED

AD NUMBER

AD243527

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; Feb 1960. Other requests shall be referred to Director, Air Force Cambridge Research Labs., Hanscom AFB, MA.

AUTHORITY

AFCRL ltr, 3 Nov 1971

THIS PAGE IS UNCLASSIFIED

BEST AVAILABLE COPY

Pages 15 & 28
missing from
original document

UNCLASSIFIED

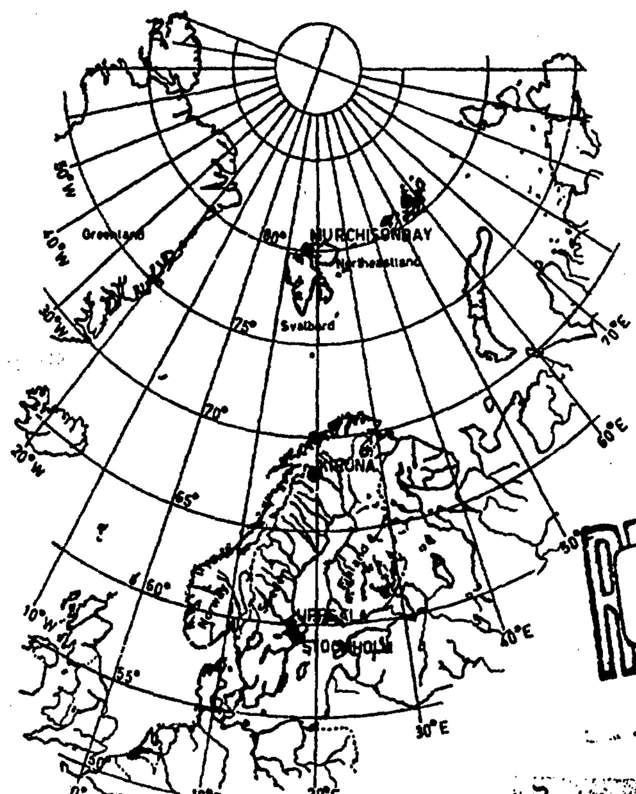
NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

AFCRC-TN-60-412

906 800

Uppsala University

INSTITUTE OF PHYSICS
COSMIC RAY GROUP



WALTMANS, UPPSALA 288 96

Uppsala, Sweden

Uppsala University
Institute of Physics Cosmic Ray Group
Uppsala, Sweden

THE DAILY VARIATION OF THE COSMIC RAY NUCLEONIC COMPONENT AT MURCHISON BAY AND UPPSALA

by
Arne Eld Sandström, Eric Dyring
and Stig Lindgren

Technical Note No. 2
CONTRACT NO. AF 61 (514)-1312

8 February 1960

The research reported in this document has been sponsored in part by the GEOPHYSICS RESEARCH DIRECTORATE, AIR FORCE CAMBRIDGE RESEARCH CENTER of the AIR RESEARCH AND DEVELOPMENT COMMAND, UNITED STATES AIR FORCE, through its EUROPEAN OFFICE and in part by the SWEDISH NATURAL SCIENCE RESEARCH COUNCIL and the SWEDISH COMMITTEE FOR ATOMIC RESEARCH.

Abstract

In both places the monitors were of the standard pattern with 12 proportional counters filled with 97 per cent enriched $B^{10}F_3$. The first and second harmonics of the mean daily variation have been determined both for yearly periods and for each sun rotation period. Vector sum diagrams for the first harmonics in the latter case are given covering the intervals 31 Aug. 1956 to 15 Aug. 1959 for Uppsala and 13 Sep. 1957 to 29 April 1959 for Murchison Bay. In some instances a considerable phase shift has taken place from one sequence of sun rotation periods to another. These phase shifts were not contemporary at the two stations. The first harmonic of the 12-month means displays a high degree of constancy with only a small secular phase shift. The amplitudes of the second harmonics are very small. Conditions are especially favourable concerning the deviation in the earth's magnetic field of the particles registered by the Murchison Bay monitor. Accordingly it has been possible to determine the direction of the anisotropy with a fairly good accuracy. The Murchison Bay records do not show any prominent phase shift with the K_p index. Concerning Uppsala, days with $[K_p]_{max} \leq 1^+$ may have a much later time of maximum than other days. There appears to be a small but consistent variation of the amplitude with K_p index.

Table of contents: Page

1. Introduction

When plans were made for a Swedish arctic station during the IGY it was natural to include studies of cosmic rays in the programme. This had also been one of the subjects studied at one of the Swedish arctic stations during the second polar year.

Now it was deemed essential to include a neutron pile monitor among the equipment. The plans were realized through the Swedish-Finnish-Swiss IGY-expedition 1957 - 58 to Murchison Bay (Liljequist 1959).[1]

The site of the station is on Norwegian territory. It is on the big arctic island of the Svalbard archipelago called Nordaustlandet on Norwegian maps, Spitzbergen on British maps. The geographic coordinates of the station are 80° 03′N and 18°18′E. It is nearly on the same meridian as the cosmic ray station at Uppsala (59° 55′N and 17° 55′E). It has also been established that during the IGY the neutron monitor at Murchison Bay was the closest to either of the geographic poles.

---

[1] Bibliographical references are made by means of the authors′ names and the years of publication.

The reliable continuous records from the Murchison Bay monitor start with 27 Aug. 1957. After the end of the Swedish-Finnish-Swiss IGY expedition the base was maintained for another year. However, owing to very adverse ice-conditions at the end of the 1958 summer it became impossible to refurnish the base with an adequate supply of diesel oil for the generators. As a consequence the continuous running of the latter had to end with April 1959. Thus, the C.R. records from Murchison Bay cover a stretch of 20 full months. The first year's results from the Uppsala monitor have already been published (Sandström and Lindgren 1959). To a certain extent they will also be included among the discussions in the present paper.

2. Equipment

Both monitors are of the type (Simpson, Fonger, Treiman 1953) recommended as the international standard instrument for the geophysical year. The few details in which the monitors differ from those of Simpson et al. were discribed in the paper concerning the first year's records from Uppsala (Sandström and Lindgren 1959). Because of the conditions expected at the arctic station the monitor was given some special features.

As in the Uppsala monitor a heavy paraffin-filled wooden box serves as a base supporting the core of lead. However, for the shield on top and on the sides of the pile the paraffin was put in aluminium containers instead of the wooden boxes, used in the Uppsala monitor. Although this kind of container was far more expensive than the wooden ones it was judged as far more safe from the point of view of fire hazards. In this way it was easy, also, to give all the parts of the shielding such dimensions as to make it possible to assemble the monitor for test in the laboratory at Uppsala and then remove it in pieces to be reerected at Murchison Bay with the least possible trouble.

Although the site of the arctic station was in a region believed to be comparatively free from heavy snow falls, special precautions were taken to avoid having the counting rate of the

monitor affected by snow surrounding the building. Accordingly an iron scaffold was constructed to carry the monitor at a level well above the height of any snow drifts which might possibly collect along the walls of beams supporting a thick wooden floor. The scaffold carrying the monitor stood on this floor. To prevent the paraffin boxes from falling down or getting out of place the whole construction was held together by an iron frame bolted to the wooden floor.

Precautions were also taken to avoid any disturbing snow cover upon the roof of the building. According to recommendations by persons having first hand experience at the intended site of the station the roof of the "cosmic ray house" was given the outlines of a pyramid. This shape was expected to favour the snow being blown away by the prevailing winds. The scheme turned out very well. During the second year there was very much snow at the base as a whole but conditions were still satisfactory around the "cosmic ray house". The snow never got as high as to the bottom of the monitor. Twice snow had to be removed from the roof. The bottom of the monitor is just below the upper edge of the wall. The shortest distance between the inner roof and the monitor is 100 cm. The mass of the heat insulated roof is less than 10 g/cm^2.

The electronics of the Murchison Bay monitor is a true replica of that at Uppsala (Sandström and Lindgren 1959). The decade scalers are photographed once every hour. As in Uppsala the panel carries, besides the scalers, a clock showing the day as well as the hours, and also two counters, one for the running number of the exposure and one indicating power failures. As the research station at Murchison Bay included a very complete meteorological service and the pressure was registered in an adjacent building it was deemed quite unnecessary to equip the monitor with an instrument for independent barometric measurements.

The general cosmic ray equipment included an auxiliary recording instrument, so-called centralograph, already described in a previous paper (Sandström and Lindgren 1959). From these auxiliary records the counting rates can be derived for periods

of any length from half a minute to one hour.

The power was supplied by two diesel-engined generators, one of them always being kept ready to take over the load in an emergency. The start of the diesel-engine was operated manually but the switching over from one generator to the other followed automatically. However, this could never be achieved without disturbing the cosmic ray equipment. The routine exchange of diesel generators once a week was therefore by arrangement executed at times which interfered as little as possible with the C.R. recording.

3. Tests and calibrations

Before removal to Murchison Bay the neutron monitor with all its electronic equipment was thoroughly tested at the physics laboratory in Uppsala. Further tests, although not as extensive, were carried out after the reassembling of the monitor on its final site.

The same scheme for adjustments, tests, and calibrations was followed as that already worked out for the Uppsala monitor. Amplifiers and discriminators were at all times adjusted so as to allow pulses from the proportional counters larger than 1 mV to be counted.

The monitors were calibrated by means of Ra Be neutron sources of 1 mc. Calibrations were made whenever a readjustment of amplifiers or discriminators took place as well as after repairs or at any suspicion of a change of counting rate. No regular time schedule was followed as it was our aim to disturb the continuous performance of the monitors as little as possible.

Both monitors have the tubes for positioning the neutron source approximately 15 cm above the center of each section with an auxiliary tube at the center of the monitor as a whole. However, the sections were always calibrated separately. By limiting each calibration run to 25 minutes the whole calibration could be completed within one hour. This was necessary with regard for the continuity of the records as one section could

not be calibrated without affecting the counting rate of the other. Likewise the neutron source affected the counting rate of the counter telescopes in the vicinity of the monitors.

In Murchison Bay as well as in Uppsala the two monitor sections have displayed approximately the same counting rates as far as cosmic rays are concerned. But in both places, owing to some slight displacement of the calibration tubes from exactly symmetrical positions, the counting rates of the two sections differ when exposed to the radiation from the neutron source.

With cadmium covers on the proportional counters the counting rate of the Uppsala monitor was 4 per cent of the normal counting rate with the cadmium tubes removed, while that of the Murchison Bay monitor was only 2.5 per cent. In both cases it was constant all along the plateau of the counters.

4. The primary data

During Sept. 1957 the average counting rate of the Murchison Bay monitor was 420 c/min., while that of the Uppsala monitor was as low as 400 c/min. The Murchison Bay records cover the period of minimum intensity of the nucleonic component as well as what appears to be the start of a slow increase. The monthly averages appear to follow one another comparatively closely(Fig.1 regardless of whether all days are included or only those with K_p indices less than 3^+ (main phase of Forbush decreases excluded).

In the whole set of data from the Murchison Bay monitor only 17 days are affected by breaks in the records of such an extent as to make them unsuitable for harmonic analysis. Breaks in the records have also caused the exclusion of 29 days from the 24 months of data from the Uppsala monitor between 1 Sept. 1957 and 31 Aug. 1959.

For both monitors there are instances in which days could be saved for the harmonic analysis by interpolating values for single hours or, in a few cases, two consecutive hours. In such cases great care has been exercised. In no case single events

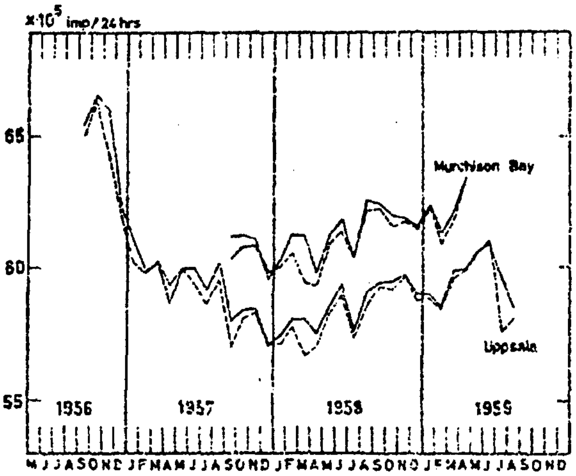


Fig.1. Monthly means of the 24-hr values of the nucleon component in Uppsala and Murchison Bay. Full lines: days with $[K_p]_{max} \leq 3^+$. Dotted lines: all available days.

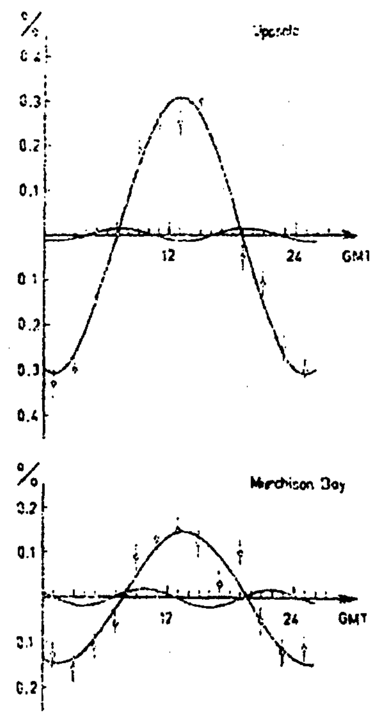


Fig.2. First and second harmonics of the mean daily variation for 1 Sep. 1957 to 31 Aug. 1958 at Murchison Bay and Uppsala. The statistical fluctuations are indicated.

or abrupt intensity changes are known to have taken place during the interval for which such an interpolation was performed. The majority of interpolations took place in connection with calibrations of the monitors. Therefore, it ought to be remembered also, that although its counting rate is affected, the half of the monitor not being calibrated can still be used for checking that no sudden changes take place in the intensity of the nucleonic component. The meson telescopes mounted in the same places as the two monitors serve for checking the C.R. intensity in a general way during periods where values are lacking from other causes.

All data have been referred to intervals of 2 hours. They have been reduced to an atmospheric pressure of 1010 mb (the yearly average for Uppsala is 1008 mb and that for Murchison Bay 1012 mb). The pressure coefficient - 0.737 per cent/mb has been adopted for both the monitors (Sandström 1958, Sandström and Lindgren 1959).

5. The daily variation

The harmonic analysis has been carried out by means of the electronic computing machine BESK in Stockholm. The points of measurement constitute a time series. Therefore, it is difficult to calculate the standard error. In some previous papers (Sandström 1955, Sandström and Lindgren 1959), this difficulty was surmounted by exchanging the standard error for another limit of error. The latter was based on the assumption that the error in the difference between the daily mean and the number of pulses during each 2-hr period was twice the standard deviation of each point of measurement (Sandström 1955). The error determined in this way will give a confidence of 90 - 99 per cent. It meets the purpose well when high confidence is desirable. However, comparisons become difficult with other papers, where, usually, limits of error are based only on the Poisson distribution of pulses. In the present paper we have therefore returned to this method of defining the accuracy.

At the same time it appears to us essential to determine the

limits of error so as to correspond to real facts. This can be done by calculating the standard error from the residuals of the points of measurement after fitting the first harmonic, resp. the sum of the first and second harmonics. The deduction of the formulas for this error will be given in an appendix to Technical Note No 3. In some of the clock diagrams we have indicated also these limits of error by circles. It is our opinion that this kind of error should be employed for the calculation of significances rather than that deduced solely from an assumed Poisson distribution of pulses. The standard deviation of the points of measurement from the resulting curve will evidently include all statistical fluctuations. There is no constant relation between the two kinds of errors. That including all statistical fluctuations is usually bigger than that covering only the Poisson distribution. Concerning the additional variations we wish to remark that one of us (Dyring 1960) has found that the statistical fluctuations calculated according to Poisson's law have to be multiplied by a factor of 1.2 to cover the actual hour by hour fluctuations.

The yearly mean daily variations of the nucleonic component as recorded in Murchison Bay and Uppsala during the period 1 Sept 1957 to 31 Aug. 1958 are shown in Fig. 2. The statistical variations are also plotted for each 2-hour interval. The figure displays how the points of measurement are distributed relative to the first and second harmonics. A corresponding diagram for the records from the Uppsala monitor from 1 Sept. 1956 to 31 Aug. 1957 has been published in a previous paper. A comparison does not display any differences in either phase or amplitude between the two yearly means as recorded by the Uppsala monitor.

The amplitude of the first harmonic is evidently smaller at the latitude of Murchison Bay than at the latitude of Uppsala. This is displayed also by the clock diagrams in Figs. 3 and 4. The phase difference is 45 minutes in both cases. A small phase shift is indicated by the records from the Uppsala monitor durin three consecutive years (Fig. 5). The small amplitude at Murchison Bay causes an error in the time of maximum approximately twice as big as that affecting the time of maximum at Uppsala. (Table 1). Concerning the phase difference between Uppsala and

Table 1

a) Standard error according to the Poisson distribution of primary values
b) Standard error calculated from residuals after fitting first harmonic
c) Standard error calculated from residuals after fitting first + second harmonics

Station Int.number	Period	Amplitude of first harmonic				Phase of first harmonic			
		Per cent of daily mean	Standard error			GMT	Standard error in min.		
			a)	b)	c)		a)	b)	c)
Uppsala B 003	1 Sep.1956-31 Aug.1957	0.322	0.010	0.013	0.011	1255	7	9	8
	Calendar year 1957	0,333	0,010	0,020	0.017	1244	7	14	12
	1 Sep.1957-31 Aug.1958	0.306	0,010	0.016	0.017	1257	8	12	13
	Calendar year 1958	0.219	0,010	0.010	0,011	1329	11	11	11
	1 May 1958-30 Apr.1959	0,217	0.010	0,017	0,015	1329	11	18	16
	1 Sep.1958-31 Aug.1959	0,222	0.010	0,018	0,015	1324	10	18	15
	26 Aug.1957-30 Apr.1959	0.263	0.008	0.012	0.011	1315	7	10	9
	1 Sep.1956-31 Aug.1959	0.283	0.006	0.011	0.011	1303	5	9	9
Murchison Bay A 010	1 Sep.1957-31 Aug.1958	0.147	0,010	0.015	0,016	1340	15	24	24
	Calendar year 1958	0,131	0.010	0.008	0.006	1431	17	15	11
	1 May 1958-30 Apr.1959	0.131	0,010	0,016	0.016	1414	17	29	27
	26 Aug.1959-30 Apr.1959	0.139	0,008	0,009	0.010	1406	12	15	17

Table 2

a) Standard error according to the Poisson distribution of primary values

c) Standard error calculated from residuals after fitting first + second harmonics

Station Int.number	Period	Amplitude of second harmonic			Phase of second harmonic		
		Per cent of daily mean	Standard error		GMT	Standard error in min.	
			a)	c)		a)	c)
Uppsala B 003	1 Sep.1956-31 Aug.1957	0.028	0.010	0.011	0543	79	87
	Calendar year 1957	0,040	0.010	0,017	0553	56	97
	1 Sep.1957-31 Aug. 1958	0,014	0.010	0.017	0724	164	278
	Calendar year 1958	0.009	0.010	0.011	0954	255	278
	1 May 1958 -30 Apr.1959	0,030	0.010	0.015	0842	76	115
	1 Sep.1958-31 Aug.1959	0,036	0.010	0.015	0902	62	95
	26 Aug.1957-30 Apr.1959	0.020	0.008	0,011	0734	86	124
	1 Sep.1956-31 Aug.1959	0,018	0,006	0.011	0733	71	136
Murchison Bay A 010	1 Sep.1957-31 Aug.1958	0,020	0.010	0,016	0956	110	178
	Calendar year 1958	0,019	0.010	0,006	0125	117	76
	1 May 1958-30 Apr.1959	0.027	0.010	0.016	0346	82	132
	26 Aug.1957-30 Apr.1959	0.007	0,008	0.010	0422	246	327

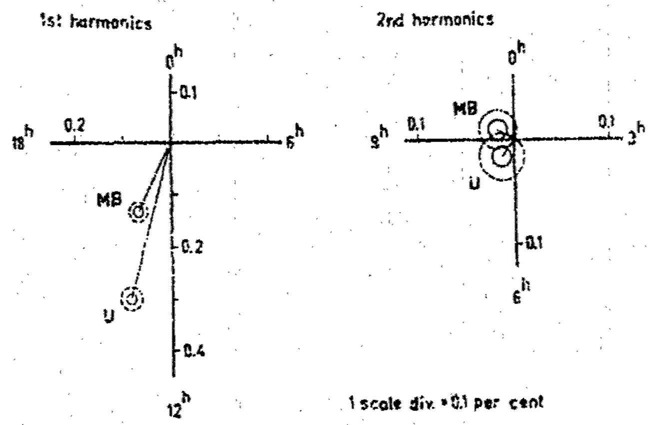


Fig.3. First and second harmonics of the nucleon component 1 Sep. 1957 to 31 Aug. 1958. MB indicates Murchison Bay and U Uppsala. Full circles: standard error from Poisson distribution. Dotted circles: standard error calculated from residuals after fitting first and second harmonics.

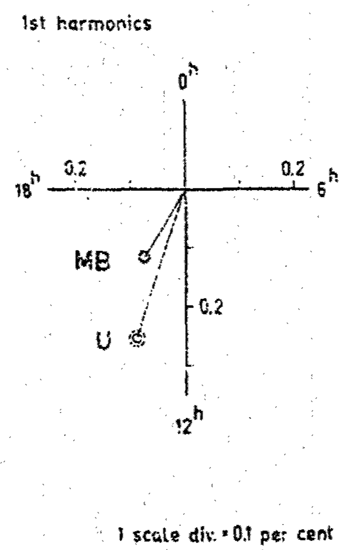


Fig.4. First harmonic for the mean daily variation of the nucleon component 26 Aug. 1957 to 30 Apr. 1959. MB indicates Murchison Bay and U Uppsala. Compare text to Fig. 3.

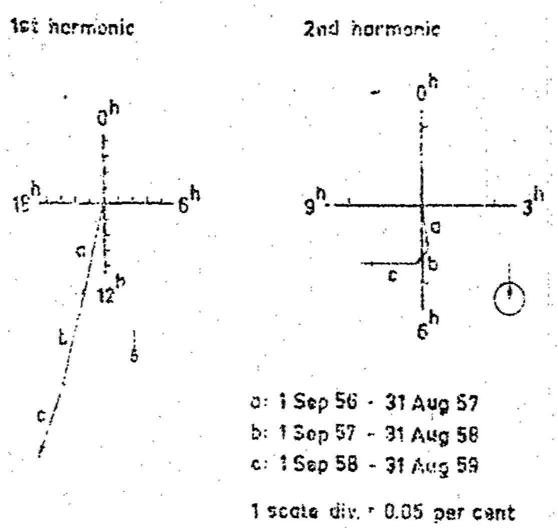


Fig.5. Vector sum diagrams for the first and second harmonics of the nucleon component at Uppsala.

Murchison Bay it undoubtedly exists even with due regard for the wider limits of error deduced from the standard deviations of the points of measurement from the first harmonic and 94 per cent confidence is being demanded (Table 1).

Turning to the vector sum diagram of the yearly means from Uppsala (Fig.5) we note that a small but persistent phase shift is indicated during three consecutive 12-monthly periods. It ought to be remarked, however, that there appears to be a phase difference of 105 minutes between the two calendar years 1957 and 1958. This difference is far outside any limits of error. The reason for such a shift depending on the starting point for the twelve -monthly periods is more easily understood after studying the vector sum diagrams in Fig. 6. These diagrams represent the phase and amplitude of the first harmonic of the mean daily variation for separate sun rotation periods. Naturally, the influence from the statistical fluctuations will be considerable although very few days had to be excluded. Although such an exclusion of a couple of days from a 27-day period usually does not affect the mean values of either the phase or the amplitude there are instances, especially during periods with a small amplitude, when a considerable change is caused by excluding only one single day (Sandström and Lindgren 1959). Therefore, the means for the sun rotation periods have been calculated using exactly the same days for both stations. In general the Murchison Bay records display a small amplitude. Consequently the random fluctuations will tend to mask most of the phase variations. For both stations it can be said that in most instances where there is a considerable variation in phase the amplitude is small and consequently the whole phase change can be regarded as due to a random distribution around a mean. In other instances the more or less persistent trend of the phase indicates variations which apparently are real.

As far as the phase is concerned the vector sum diagram for Uppsala does not show any prominent deviations from the mean value for the whole period 31 Aug. 1956 to 15 Aug. 1959. The vector sum diagram for Murchison Bay displays a different picture. Starting with August and through October 1958 the phase

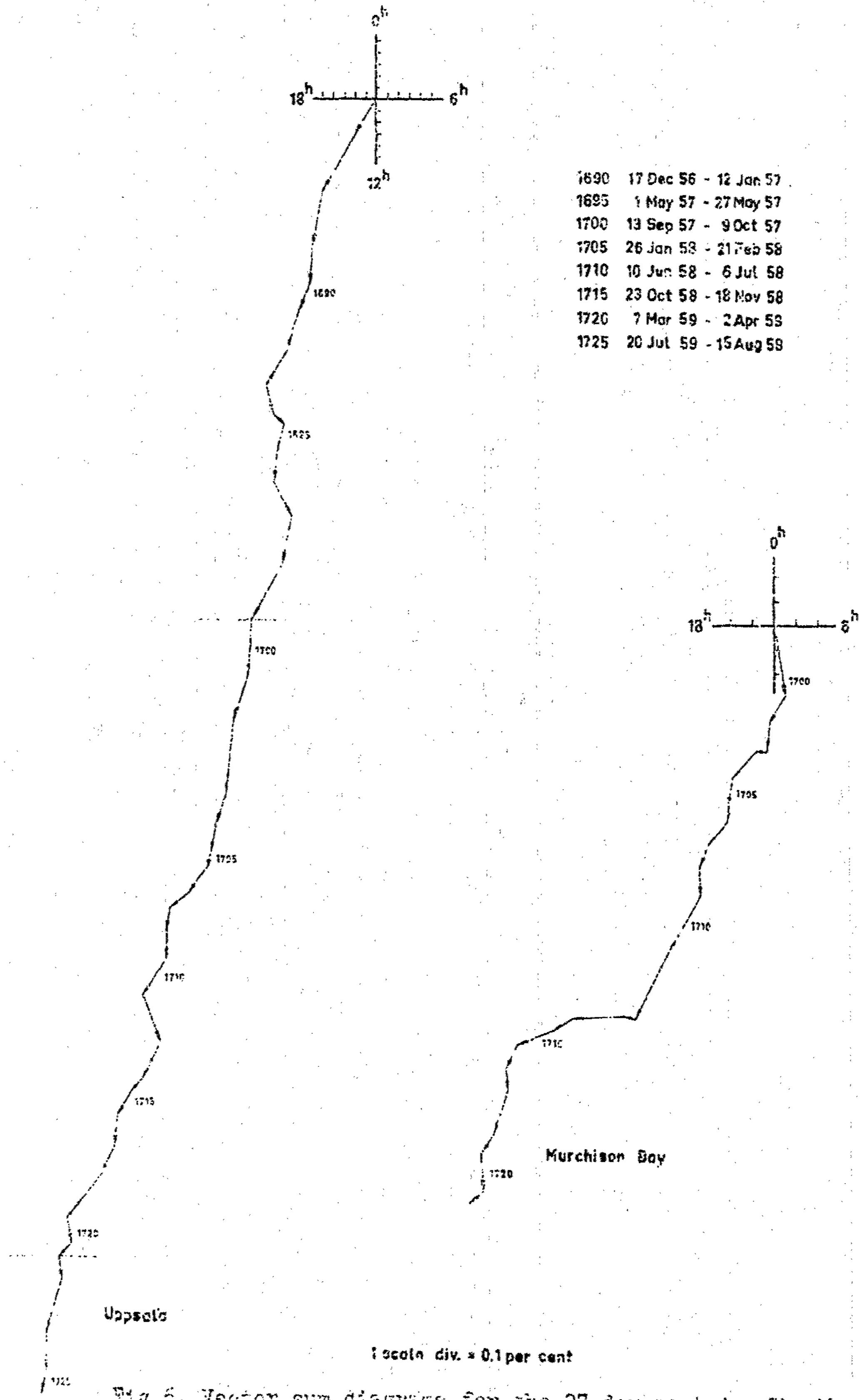


Fig.6. Vector sum diagrams for the 27-day periods. The Murchison Bay vectors are twice the scale of those for Uppsala.

differed definitely from that before as well as after this period. It appears also as if a phase shift had taken place shortly after the start of recording. However, the discussion will be confined to the other two instances when a phase shift appears to have taken place. Accordingly.we calculate the means for the periods 10 Oct. 1957 - 2 Aug. 1958; 3 Aug.-18 Nov. 1958, and 19 Nov.1958-29 April 1959. The result is illustrated by the clock diagram in Fig.7. With due regard for the standard error it is evident from this diagram that the phase is the same during the first and third periods. Combining these two periods we find a time of maximum intensity of 1328 GMT ± 17 min. For the period 3 Aug.-18 Nov. 1958 the time of maximum was 1723 GMT ± 31 min. From Fig.7 it is apparent that the phase shift is real. The phase shift is $56^{o} \pm 22^{o}$. It is clearly indicated still if we demand a confidence of 95 per cent.

It is possible that the phase shift of the mean daily variation in Uppsala for the two calendar years as compared to the three twelve-monthly periods is due, also, to short periods of a differin. phase. A study of the details of the vector sum diagram for this station (Fig.6) reveals the existence of such periods although they are less conspicuous than in the Murchison Bay records. The clock diagram in Fig.8 illustrates the mean daily variation during the three periods 31 Aug. 1956-7 March 1957; 8 March-20 July 1957; and 21 July 1957-3 March 1958. This case exhibits a striking resemblance to that illustrated in Fig.7. It is evident that during the middle period the phase differed from that during the two adjacent periods. A phase difference between the two latter is also indicated, the time of maximum being 1327 GMT ± 8 min. for the first one and 1305 GMT ± 8 min. for the third period. During the intervening time, 8 March-20 July 1957, the time of maximum was 1117 GMT ± 16 min. This period with an early maximum falls inside the calendar year 1957. In the following year there does not exist any prolonged period with such a comparatively early maximum (during the sun rotation period No 1711 the mean time of maximum was 1030 GMT). If the period 8 March-20 July is excluded from the 1957 records the mean time of maximum will be practically the same as that during 1958.

The two vector sum diagrams (Fig.7) reveal also that the variations of the amplitude in the two places are not well correlated. This is especially true for the last quarter of 1957 and the first quarter of 1958.

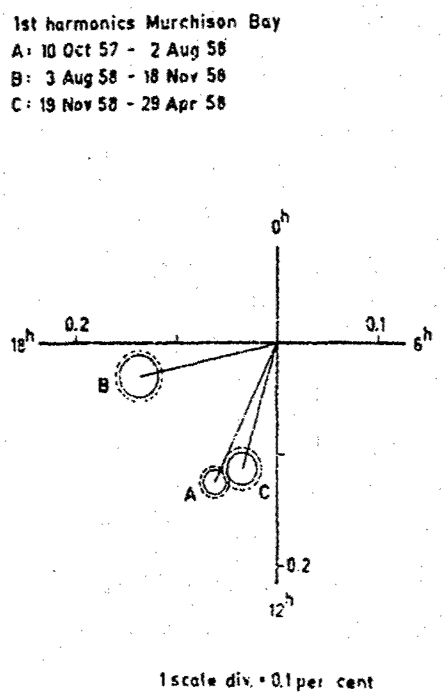


Fig.7. Phase shifts of the first harmonic of the nucleon component registered at Murchison Bay. Compare text to Fig. 3.

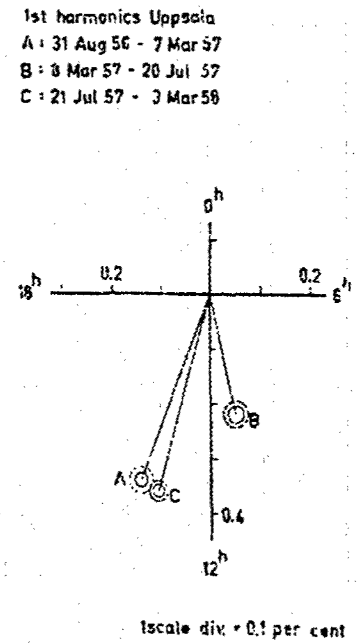


Fig.8. Phase shifts of the first harmonic of the nucleon component registered at Uppsala. Compare text to Fig.3.

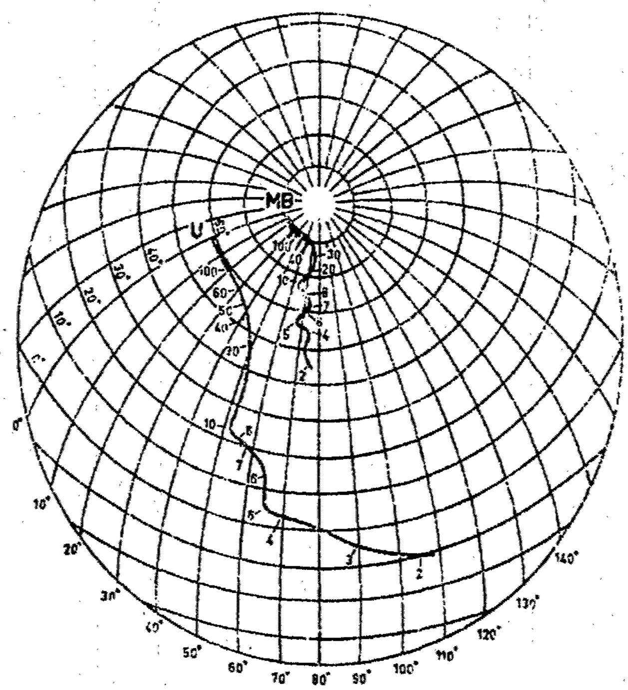


Fig.9. Longitude and latitude corrections for the zenith directions in Uppsala (U) and Murchison Bay (MB). The rigidities are indicated in the figure. The unit is 10^9 eV/c.

6. The second harmonic

The amplitude of the second harmonic is very small. It is of the same order of magnitude in Uppsala and Murchison Bay (Fig.3). Both phase and amplitude are severely affected by the exclusion of only a few days (Sandström and Lindgren 1959). Further, as was shown by the first year's records from the Uppsala monitor periods exist which have a prominent second harmonic while the amplitude of the first harmonic is of the same order of magnitude or even less (Sandström and Lindgren 1959).

The three consecutive 12-monthly periods combined with the calendar years 1957 and 1958 from the Uppsala monitor provide running means for a study of the second harmonic (Table 2). The vector sum diagram for the three 12-monthly periods is to be found in Fig. 5. This diagram as well as the figures in Table 2 strengthen the picture of a considerable variation both in phase and amplitude. If we consider only the Poisson distribution of the number of pulses during the 2-hr intervals the existence of the second harmonic does not seem to be in doubt. If the standard errors are calculated from residuals of the points of measurement after fitting the first plus second harmonics the second harmonic appears doubtful. A 94 per cent confidence is in any case unattainable.

7. The longitude correction

Terrella experiments (Malmfors 1945, Brunberg 1953, Brunberg and Dattner 1953) made it possible to calculate the asymptotic directions of primaries for various rigidities and directions of registration (Brunberg 1956). The knowledge thus gathered can be utilized to determine the true direction of the anisotropy responsible for the daily variation (Brunberg and Dattner 1959). However, several obstacles have to be overcome before it becomes possible to determine the correction for the deviation of the primaries in the geomagnetic field with a precision corresponding to that of present day C.R. registrations (Dorman 1957). Three

factors are involved: the rigidity spectrum of the primaries, the solid angle of acceptance of the detector, and the shape of the geomagnetic field. The multiplicity of the nucleon production is a function of the rigidity. It is thus a part of the first one of the three factors listed. The effective rigidity to be ascribed to the primaries of the nucleonic component at the geomagnetic latitude of Uppsala has been discussed elsewhere (Sandström and Lindgren 1959). Concerning Murchison Bay especially favourable conditions govern the angular correction in the east-west plane for particles observed by the monitor in the zenith direction. At this latitude secondaries accepted by the monitor at zenith angles up to 48^0 originate from primaries having asymptotic directions inside a comparatively narrow cone (Åström 1956; compare also Fig. 32 in Brunberg 1956). Under these conditions we have found it permissible to regard the Murchison Bay monitor as observing predominantly in the zenith direction.

The longitude correction Ψ and the latitude correction Λ for the zenith direction and varying rigidities have been plotted in a diagram (Fig. 9) according to Brunberg (1956). The values have been recalculated to the geographic latitude 78^0 (Longyearbyen). In high latitudes a couple of degrees make quite a marked difference. For rigidities below 10 GeV/c the values have been calculated from the measurements by Malmfors (1945).

The corresponding curve for the zenith direction in Uppsala has been entered into the same figure. The conditions are not as favourable in this case as in the former one. Nevertheless, as has been pointed out by Åström (1956) the spherical representations by Brunberg (1956) of Ψ and Λ reveal a certain focussing effect even for latitudes down to 50^0. However, the cones limiting the asymptotic directions will not have as small a solid angle as in the case of the Murchison Bay monitor.

What concerns us most is the longitude correction Ψ'_{MB}. Fig. 9 reveals that for rigidities below 40 GeV/c this correction does not vary very much with the rigidity. Most of the primaries responsible for the nucleonic component will have rigidities below 10 GeV/c. Accordingly it appears to be realistic to put

$$\Psi'_{MB} = 72^0 \pm 5^0 \quad \text{-------------------} \quad (1)$$

calculated from Ψ_{MB} and the phase difference between the two stations would then be

$$\Psi_U = 84^\circ \pm 10^\circ \quad (3)$$

Accordingly the curves in Fig.9 indicate that the "effective" rigidity has to fall between 3 and 5 GeV/c to correspond to the same original direction of the anisotropy in both cases. This is reasonable, considering what is known of the rigidity spectrum of the primaries generating the nucleonic component.

Recent studies of the latitude effect have shown that the actual magnetic field configuration near the surface of the earth has a certain influence on the geomagnetic cut off of C.R. (Rothwell 1958, Sandström 1958, Pomerantz, Sandström, Potnis, and Rose 1959). It has not been proved that there exists a corresponding effect on the trajectories of the primaries. Most of the length of each trajectory will certainly fall in a region where the geomagnetic field is regular and free from anomalies. In Murchison Bay as well as in Uppsala the magnetic meridian plane nearly coincides with the geographic meridian. Dip and geomagnetic coordinates are listed in Table 3.

Table 3

	Uppsala	Murchison Bay
Geogr. lat.	$59^\circ 51'$N	$80^\circ 03'$N
Geogr. long.	$17^\circ 55'$E	$18^\circ 15'$E
Geomagn. lat.	$58^\circ 36'$	$75^\circ 30'$
Geomagn. long.	107°	$137^\circ 30'$
Dip	$72^\circ 30'$	$82^\circ 30'$
Declination	$0^\circ 30'$E	$1^\circ 0'$E

8. The direction of the anisotropy

The direction of the observed anisotropy is most conveniently defined through the angle α it makes with the radius vector

from the sun. For this angle we have

$$\alpha = \lambda + \tau + \Psi \qquad (3)$$

Here λ represents the geographic longitude (Table 3). τ is the difference, in angular measure, between the time of maximum and noon i.e. $\tau = 15^{0}(t_{max} - 12)$. The values of τ for the periods under discussion are listed in Table 4. The value of the longitude correction Ψ for Murchison Bay is that given by eq. (1). For Uppsala α has been calculated both with a longitude correction according to eq. (2), viz. deduced independently of any comparisons with Murchison Bay, as well as with that according to eq. (3). The results covering the period of recording at Murchison Bay are listed in Table 4, where α_U refers to Uppsala and α_{MB} to Murchison Bay. Naturally, the way of deducing the longitude correction represented by eq. (3) results in nearly coinciding pairs of values in the two last columns of Table 4. Nevertheless, the direction of the anisotropy as recorded by the Uppsala monitor will still be inside the limits of error assigned to the longitude correction according to eq. (2).

Table 4.

Period	τ_U	τ_{MB}	α_U		α_{MB}
			$\Psi=71^0$	$\Psi=84^0$	
1 Sep.1957- 31 Aug.1958	$14.5^0 \pm 5^0$	$25.0^0 \pm 5^0$	$103^0 \pm 20^0$	$116^0 \pm 15^0$	$115^0 \pm 10^0$
Calendar year 1958	$22.3^0 \pm 5^0$	$37.7^0 \pm 5^0$	$111^0 \pm 20^0$	$124^0 \pm 15^0$	$128^0 \pm 10^0$
1 May 1958- 30 Apr.1959	$22.3^0 \pm 5^0$	$33.5^0 \pm 5^0$	$111^0 \pm 20^0$	$124^0 \pm 15^0$	$124^0 \pm 10^0$

In the discussion concerning the vector sum diagrams in Fig.6 and the clock diagrams in Figs.7 and 8 it was remarked that the yearly mean of the daily variation might vary slightly with the starting points of the twelve-monthly periods. This is apparent from the values in Table 4 also. As long as we do not know the reason for the non-periodical phase shifts causing

these variations we are not able to eliminate them. As will be shown in the final discussion influences from short period variations are probably eliminated to a large extent in every yearly mean. Therefore, it should be emphasized that the present discussion on the direction of the anisotropy is concerned with 12-monthly averages.

A simple way of studying the directions of C.R. anisotropies is to resolve the corresponding vector into components along two axes, one along the radius vector from the sun and one along a tangent to the orbit of the earth (Sandström 1956). Concerning the records from Murchison Bay there is no doubt about the existence of the component along the radius vector. It is directed towards the sun. Exactly the same can be said of the Uppsala records if the longitude correction according to eq. (3) is used. A radial component towards the sun is still present when the longitude correction is that given by eq. (2).

9. The phase as a function of the K_p index.

Concerning the meson component there exists comparatively strong evidence that the phase of the daily variation depends on the prevailing geomagnetic conditions (Sekido and Kodama 1952, Sandström 1955). For a similar treatment of the present data on the nucleonic component the days were divided into classes determined by the maximum K_p index of each day (Sandström 1955). These classes are listed in Table 5 together with the number of days from each station and period. For the sake of comparison between Uppsala and Murchison Bay one of the periods was selected so as to include the whole set of neutron monitor records from the latter place. As the records from Uppsala show good agreement in phase as well as in amplitude for the three 12-month periods illustrated by the vector sum diagram in Fig.5 it was considered appropriate to combine these three periods into one.

Table 5

Class of days	$[K_p]$ max	Number of days available for analysis		
		26 Aug.1957-30Apr.1959		1 Sep.1956-31 Aug.1959
		Murchison Bay	Uppsala	Uppsala
I	$[K_p]_{max} \leqq 1^+$	12	12	28
II	$1^+ < [K_p]_{max} \leqq 3^+$	226	216	398
III	$3^+ < [K_p]_{max} \leqq 5^+$	270	263	469
IV	$5^+ < [K_p]_{max} \leqq 7^+$	67	70	125
V	$7^+ < [K_p]_{max} \leqq 9^o$	20	19	35

A study of this kind has already been published concerning the first year of the Uppsala records (Sandström and Lindgren 1959). As regards the days employed in the comparison between Uppsala and Murchison Bay those belonging to class I are exactly the same in both cases. In classes II and III the number of days is so big as to make the few cases of odd days completely insignificant. Concerning class IV the available number of days is anyhow so low as to necessitate the employment of as many days as possible for the sake of the statistical fluctuations. Moreover, variations correlated with the geomagnetic conditions might be responsible for some of the day to day phase shifts which undoubtedly exist. From this point of view it appears desirable to accumulate as many days as possible for each K_p index class. If the number of days in one group is as large as 60 the removal of a few days does not affect either amplitude or phase in a serious way (Sandström and Lindgren 1959).

Concerning the most disturbed days (class V) we encounter another problem. These days are usually those on which a prominent Forbush decrease occurred. An ordinary linear trend correction is then often inadequate for the separation of the true daily variation from the singular event (Sandström and Lindgren 1959).

Table 6.

First and second harmonics for days divided into classes according to $\left[K_p\right]_{max}$.
The limits of error are all standard errors calculated from the Poisson distribution of primary data.
The amplitudes are in per cent of the daily mean.
The limits of error for the phase are in minutes.

Station Int. Number	Class of days	26 Aug. 1957–30 Apr. 1959				26 Aug. 1957–30 Apr. 1959 with exclusion of the period 3 Aug.–18 Nov. 1958			
		First harmonic		Second harmonic		First harmonic		Second harmonic	
		Amplitude per cent	Phase GMT	Amplitude per cent	Phase GMT	Amplitude per cent	Phase GMT	Amplitude per cent	Phase GMT
Uppsala E 003	I	0.404 ± 0.053	1741 ± 3[illegible]	0.022 ± 0.053	1148 ± 552	0.425 ± 0.065	1806 ± 35	0.031 ± 0.065	0005 ± 481
	II	0.281 ± 0.013	1327 ± 11	0.018 ± 0.013	0631 ± 166	0.281 ± 0.014	1336 ± 11	0.018 ± 0.014	0542 ± 175
	III	0.235 ± 0.011	1314 ± 11	0.033 ± 0.011	0658 ± 76	0.223 ± 0.012	1332 ± 12	0.035 ± 0.012	0500 ± 79
	IV	0.301 ± 0.022	1249 ± 17	0.029 ± 0.022	1038 ± 174	0.401 ± 0.024	1250 ± 14	0.030 ± 0.024	0732 ± 183
Murchison Bay A 010	I	0.190 ± 0.052	1501 ± 63	0.064 ± 0.052	0906 ± 186	0.179 ± 0.064	1421 ± 82	0.023 ± 0.064	0638 ± 638
	II	0.144 ± 0.012	1415 ± 19	0.010 ± 0.012	0149 ± 275	0.126 ± 0.014	1349 ± 25	0.011 ± 0.014	0714 ± 292
	III	0.107 ± 0.011	1340 ± 24	0.017 ± 0.011	0710 ± 148	0.121 ± 0.012	1337 ± 23	0.028 ± 0.012	0648 ± 9[illegible]
	IV	0.234 ± 0.022	1447 ± 22	0.067 ± 0.022	0444 ± 75	0.287 ± 0.024	1344 ± 19	0.068 ± 0.024	0517 ± 81

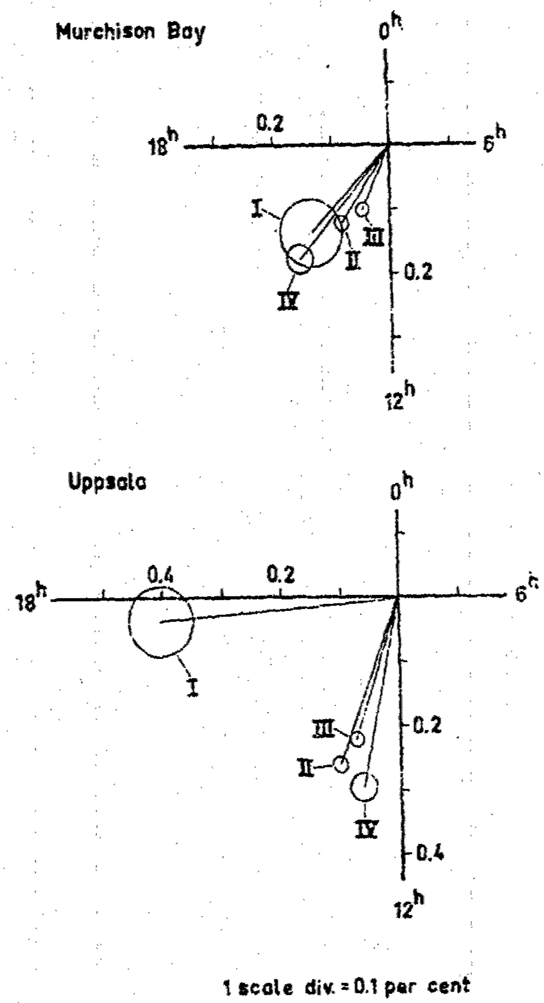


Fig.10. The mean first harmonics for days divided into classes according to their maximum K_p index, Period: 26 Aug. 1957 to 30 Apr. 1959

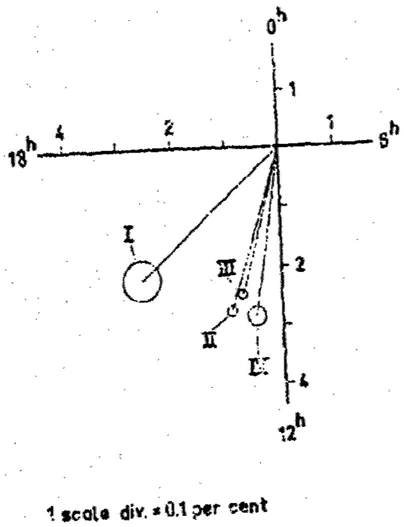


Fig.11. The mean first harmonics at Uppsala for days divid: into classes according to their maximum K_p index. Period of 36 months: 1 Sep. 1956 to 31 Aug. 1959.

Therefore, no vector corresponding to class V has been included in the clock diagrams of Figs.10 and 11 (Tables 6 and 7). However, in the Uppsala records there is a sufficient number of days available during which C.R. conditions were undisturbed despite the very high K_p indices. These days have been employed for a special study illustrated in Fig. 12.

Table 7.

First and second harmonics for days divided into classes according to $[K_p]_{max}$. Uppsala 1 Sep. 1956-31 Aug. 1959.

The limits of error are all standard errors calculated from the Poisson distribution of primary data.

The amplitudes are in per cent of the daily mean.

The limits of error for the phase are in minutes.

Class of days	First harmonic		Second harmonic	
	Amplitude per cent	Phase GMT	Amplitude per cent	Phase GMT
I	0.347 ± 0.034	1519 ± 22	0.010 ± 0.034	0034 ± 779
II	0.298 ± 0.009	1315 ± 7	0.006 ± 0.009	0709 ± 344
III	0.261 ± 0.009	1306 ± 8	0.040 ± 0.009	0733 ± 52
IV	0.295 ± 0.017	1240 ± 13	0.010 ± 0.017	0106 ± 390

Concerning Murchison Bay (Fig.10) the vectors for all four classes of days fall together inside the limits of error. Also the contemporary Uppsala records display small variations, the class I days excepted. Despite the small number of days the limits of error are sufficiently narrow to prove the reality of the phase shift for quiet days (class I). Likewise there is little doubt that on class IV days the maximum tends to appear earlier than on the days of classes II and III. Space forbids the introduction into Figs.10 and 11 of the standard errors based on the residuals of the experimental points after fitting the first plus second harmonics.

During the period 31 Aug. 1956 - 31 Aug. 1957 the phase of

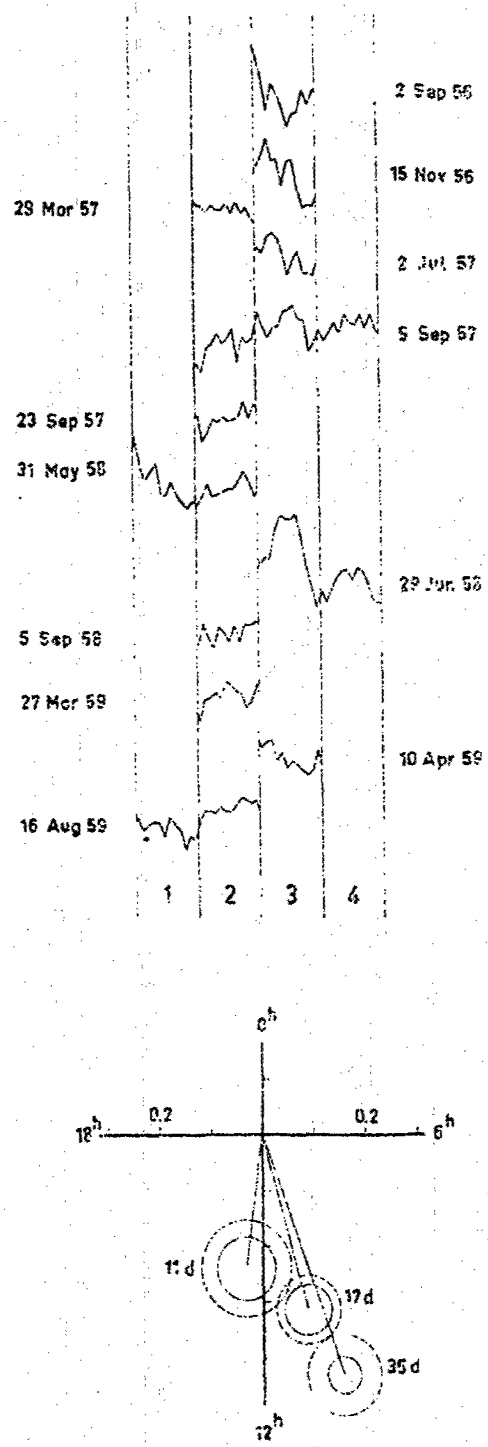


Fig. 12. Mean daily variation for days with $[K_p]_{max} > 7^+$. The vector marked 11 days represents the days illustrated by the curves in columns 1,2, and 4. The vector marked 17 days shows phase and amplitude when those days are added which are illustrated by the curves in column 3. The third vector (35 days) represents the mean of all available days with $[K_p]_{max} > 7^+$. The curves in the upper part show the variation in relative intensity for each day.

the class I days in Uppsala was the same as that of classes II and III. The introduction of accurately calculated limits of error does not change this aspect. The phase shift for the class I days from this period to the following 12-month period is more than twice the standard errors calculated from the Poisson distribution. From this point of view it is perhaps not suitable to found an analysis on as long a period as 36 months (Table 7). But, this special shift excepted, the changes from one year to another are small. A period over several years will present, through better statistics, a more accurate determination of the phase shifts between the other classes of days. From Fig. 11 can be seen that the class IV days certainly have an earlier mean time of maximum than days with $[K_p]_{max} \leqq 5^+$. In all the three clock diagrams (Figs. 10 and 11) the phase appears to be nearly the same for classes II and III.

The long period of 36 months has also yielded a sufficient number of days with $7^+ < [K_p]_{max} \leqq 9^0$ for the study illustrated in Fig. 12. In this case we have found it important to calculate also the limits of error from the residuals after fitting the first and second harmonics (Table 8). They are illustrated by dotted circles in Fig. 12. During the whole period 11 days of class V were found which did not have any single event disturbing the normal variation. The 2-hr values for each single day can be read from the curves in columns 1,2,and 4 in the upper part of Fig. 12. To these 11 days can be added six days with small Forbush decreases or parts of such decreases (curves in column 3, Fig 12). The corresponding vectors are to be found in the clock diagram in the lower part of Fig.12. In the first case the phase is nearly the same as for the class IV days in Fig.11. In the second case it lags 22^0 behind (1.5 hrs). The amplitude has also increased. If all available days of class V are employed the phase lag increases to 27^0 and the mean amplitude becomes twice that of the group of 11 days first considered. As the added days are ones with prominent Forbush decreases it is evidently the decreases and not a change in the normal daily variation which produce the big amplitude.

Table 8.

Uppsala. Mean daily variation for days with $7^{+} < [K_p]_{max} \leq 9^{o}$

a) Standard error according to the Poisson distribution of primary values.

c) Standard error calculated from residuals after fitting first + second harmonics.

Group of days	Amplitude			Phase		
	Per cent of daily mean	Standard error		GMT	Standard error	
		a)	c)		a)	c)
11 days	0.244	0.056	0.088	1233	53	61
17 days	0.331	0.045	0.061	1103	31	58
35 days	0.457	0.032	0.072	1043	16	36

The change in phase is not as easily brought back to the same source. Nevertheless, days with $[K_p]_{max} > 7^{+}$ but undisturbed by actual decreases (11 d vector in Fig.12),have nearly the same phase and amplitude as those belonging to class IV.

The variation of the amplitude with $[K_p]_{max}$ differs from that observed for the meson component (Sandström 1955). At present the nucleon component has its biggest amplitude on days with $[K_p]_{max} \leq 1^{+}$. It decreases with increasing $[K_p]_{max}$ until $[K_p]_{max} = 5^{+}$. After that it appears to increase slightly (class IV). The same picture is offered by all the three clock diagrams (Figs. 10 and 11).

From the small spread of the vectors for the nucleonic component at Murchison Bay it follows that the direction of the anisotropy outside the earth's magnetic field depends only slightly on the disturbances causing the variations of the K_p index. The same can be said about the Uppsala values, days with $[K_p]_{max} \leq 1^{+}$ excepted. Concerning the latter the Uppsala records (Fig. 10) indicate a late time of maximum. Correcting for the

deviation of the primaries by the earth's magnetic field we find the direction of the anisotropy to be $174^\circ \pm 20^\circ$ to the evening side for $\Psi_U = 71^\circ$ (eq. 2) and $187^\circ \pm 15^\circ$ for $\Psi_U = 84^\circ$ (eq. 3). A comparison with the contemporary measurements from Murchison Bay makes both these values look meaningless. Resolving the anisotropy into radial and tangential components we find that at the latitude of Uppsala the latter would be either non-existent or smaller than that at Murchison Bay. If the correction according to eq. 3 is accepted it would even be possible that it had the opposite direction. At the same time the radial component would have a very much bigger amplitude at Uppsala than at Murchison Bay. Even considering the very wide limits of error of the longitude correction this seems contradictory.

If instead, the first year of the Uppsala records (Sandström and Lindgren 1959) is studied, the picture will be different. The same is to some extent true also of the whole 36-month period. In the first case the vector for the class I days has almost the same direction as that for the period unresolved according to the K_p index. In the second case the angles of direction will be $139^\circ \pm 20^\circ$ for $\Psi_U = 71^\circ$ and $152^\circ \pm 15^\circ$ for $\Psi_U = 84^\circ$. This appears at least more reasonable. But the erratic phase shifts still call for a special study.

During the period 26 Aug. 1957 to 30 Apr. 1959 there are only 12 days belonging to class I (Table 5). The very big amplitude of the first harmonic at Uppsala indicates that it might be possible to study the daily variation on single days. The vector sum diagrams in Fig. 13 are the result of such a study. It is interesting to note that on the first one of the 12 days under discussion the phase of the first harmonic differs considerably from the mean of the whole class of days. Because of the unavoidably big standard errors the phases are not significantly different at Murchison Bay and Uppsala. However, the removal of this particular day has a remarkable effect on the means for the remaining 11 days (Fig. 14). At Murchison Bay the phase remains the same while the amplitude increases by a factor of approximately two. At Uppsala the phase decreases. In this case, too, the amplitude increases. In Fig. 14 the dotted vector

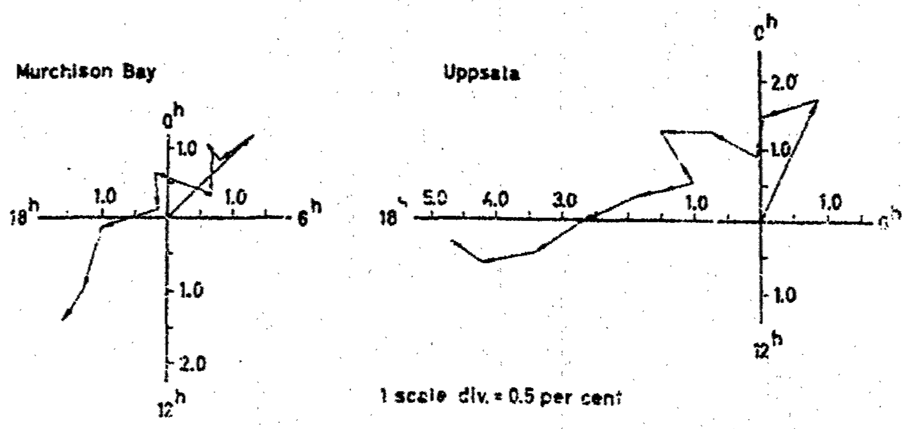


Fig. 13. Vector sum diagrams for the first harmonics of single days with $[K_p]_{max} \leq 1^+$. From the origin the vectors represent 23 and 25 Dec. 1957, 24 May, 13 Sep., 12 Oct., [illegible], 6, and 30 Nov., [illegible] Dec. 1958, 1 and 21 Jan., and 22 Apr. 1959.

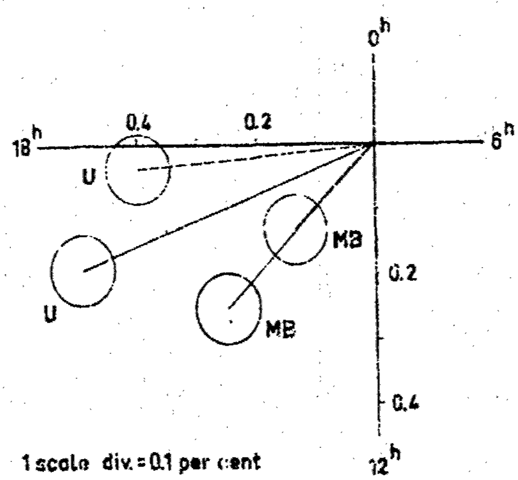


Fig. 14. Diagram showing amplitude and phase of the first harmonic for the class 1 days at Uppsala (U) and Murchison Bay (MB). Dotted vectors: all days with $[K_p]_{max} \leq 1^+$ included. Full drawn vectors: the same days exclusive 25 Dec. 1957.

BEST AVAILABLE COPY

represent the means of the original 12 days, while the full drawn vectors represent the means of the remaining 11 days.

A comparison between Figs.10 and 14 reveals that the exclusion of 23 Dec. 1957 does not bring the Uppsala and Murchison Bay vectors of the class I days into phase inside the standard errors as calculated from the Poisson distribution. However, the results indicate that 12 days is too short a period for the elimination of disturbances in the daily variation not correlated with the phenomena characterized by the K_p indices.

It ought to be observed that 23 Dec. 1957 is at the end of the recovery period after a Forbush decrease (Compare Sandström and Lindgren 1959).

It is of some interest to study how the removal of the period 3 Aug. to 18 Nov. 1958 affects the phases and amplitudes of classes I - IV. This period had a phase which differed markedly from the phase during the rest of the Murchison Bay records (Figs. 6 and 7). In the case of Uppsala the phase change as well as the change of amplitude is negligible. For Murchison Bay the shifts are significant through their consistency although they are relatively small in comparison with the limits of error. As can be seen from Fig. 15 the shifts are in the same direction in all four cases. The direction is that expected from the removal of the period with abnormal phase. The results indicate also that the late time of maximum is unconnected with the geomagnetic conditions during the period in question.

Although the amplitude of the second harmonic is very small in comparison with the limits of error there is no doubt of its existence especially for days with $\left[K_p\right]_{max} > 3^+$ (Tables 6 and 7). However, for the geomagnetically most disturbed days ($7^+ < \left[K_p\right]_{max} \leqq 9^o$) the mean amplitude does not exceed the limits of error.

The first year's records from the Uppsala monitor reveal a significant amplitude of the second harmonic for days belonging to class IV. However, for the whole period of 36 months the mean amplitude for this class is insignificant. Disregarding those cases where the amplitude is less than the limits of error no variation in phase can be observed. This might be due, partly, to the inaccuracy caused by the small amplitudes.

As can be seen from Tables 6 and 7 the values for the period

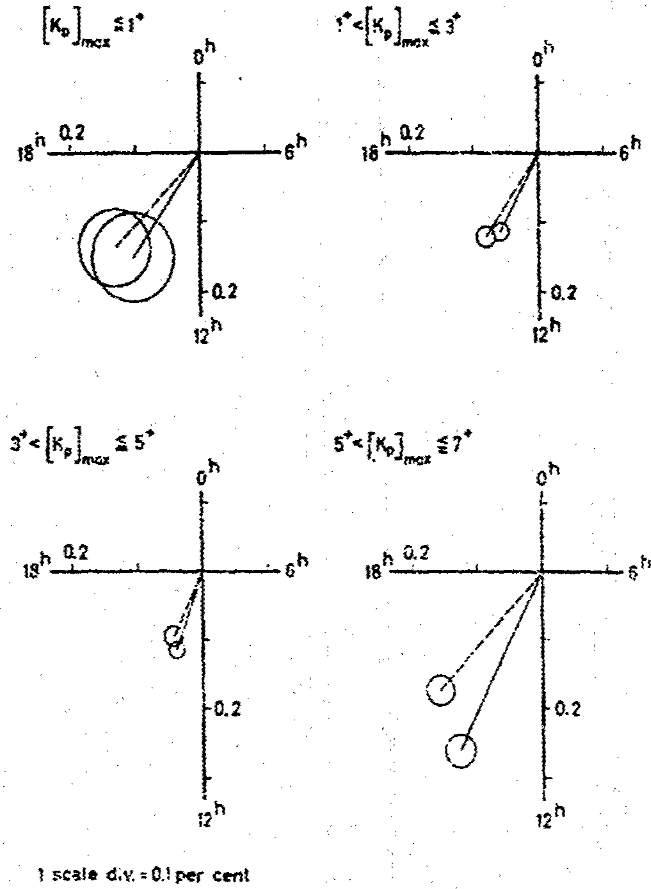


Fig. 15. Clock diagrams for the mean daily variation at Murchison Bay showing the phase shifts for the first four classes of days when the period 3 Aug. to 18 Nov. 1958 is being removed (full drawn vectors).

1 Sep. 1957 to 30 Apr. 1959 are more consistent than those for the 36 month period. The scattering of the phase values is further decreased by removal of the three. 27 - day periods with strongly deviating phase at Murchison Bay (right part of Table 6). Naturally the magnitude of the standard errors forbids definite conclusions. Still this might be an indication that the second harmonic is connected with certain kinds of disturbances just as the increase of amplitude with $\left[K_p\right]_{max}$ might indicate that the second harmonic originates from the same causes as do the geomagnetic disturbances.

10. Conclusion

Undoubtedly there is a considerable day to day variation both in phase and amplitude. In many cases these variations reveal themselves in the curves giving the 2-hr values of the nucleon component. They have also been commented upon by Firor et al. (1954), and by Mc Cracken (unpublished thesis 1959). It is possible that some of these variations are due to local effects. In other cases, for instance 28 June 1958 (Fig.12) it is doubtful whether the big amplitude is to be ascribed to the normal daily variation or to some superimposed single event. Under these circumstances the mean value over a long period becomes important not only as a means of reducing the influence of statistical fluctuations. If, as most of the evidence indicates, the main component of the daily variation is due to a particle wind blowing along the earth's orbit, the tilting of the axis of rotation of the earth will possibly give rise to a small seasonal variation in the amplitude. This seasonal variation will disappear in the yearly mean. A sidereal component with constant amplitude will also disappear in the yearly mean. Should the amplitude not be constant it would still be diminished to a minimum through the process of averaging.

Dattner and Venkatesan (1959) have listed seven possible components of the diurnal variation. The existence of these components has been derived from the theory by Alfvén (1954) concerning the origin of cosmic rays. One of these components

is identical with the solar time variation which can be ascribed to an excess of particles sweeping along the earth's orbit with an angular velocity exceeding that of the earth. This component is one of the main subjects of the present investigation. Its existence is well established in the nucleon component as well as the meson component. One of the other components should be present only during years of low solar activity and, therefore, it is unimportant in the present period of recording. Of the other five components three have a radial and two a tangential direction. Two of the radial components will more or less cancel one another in an annual average. This also indicates the yearly mean as a less complicated object of study than short period means.

One of the tangential components of Dattner and Venkatesan is connected with the recovery after magnetic storms. It should play a prominent part during the present period. As yet the records from Uppsala and Murchison Bay have not been subjected to a search for this component.

It has not been our aim at present to employ the neutron monitor records from Uppsala and Murchison Bay for sorting the components of Dattner and Venkatesan. These intricate problems will undoubtedly have to be solved by studies of the daily variation as measured by stations distributed all around the world and with the meson component included. They are mentioned here only as one of the reasons why means for whole passages of the earth around the sun are supposed to present a less complicated daily variation. Nevertheless, as is shown by the Murchison Bay and Uppsala records, the yearly means can be affected by non-recurrent periods with a differing phase (Figs. 7 and 8). If only they were contemporary the existence of such periods could be explained by the appearance or disappearance of one or two of the components listed by Dattner and Venkatesan. As in this case non-contemporary phase shifts occur at two stations on the same meridian it appears as if an explanation through such somponents is invalidated.

When means for periods as short as one month or 27 days are being studied it is necessary to bear in mind that the day to day variability will play a prominent part. This fact might be res-

the earth.

The Murchison Bay records reveal that the anisotropy makes an angle of more than 90^{o} with the radius vector from the sun. Therefore, if resolved in one tangential and one radial component the mean yearly anisotropy will have a radial component directed towards the sun. Making it a condition that the direction of the anisotropy should be the same when calculated from the Uppsala records as when calculated from the Murchison Bay records, a longitude correction can be found for Uppsala.

During three consecutive years the Uppsala records reveal only minor changes in the phase and amplitude of the yearly mean first harmonic. When short periods are analyzed phase shifts are found which do not appear simultaneously in the records from the two stations.

At Murchison Bay the first harmonic exhibits a small negative phase shift with increasing values of $\left[K_p\right]_{max}$. At Uppsala the first harmonic displays clearly the same small phase shift, days with $\left[K_p\right]_{max} \leqq 1^+$ excepted. In this latter case the phase is sometimes strongly shifted towards late hours, and the amplitude increases considerably. In one case this has been shown to be due to one single day with strongly differing phase and amplitude. This day had the same phase and amplitude in Uppsala and Murchison Bay but affected the means for the two stations in different ways.

The amplitude of the second harmonic is very small.

We shall postpone further discussion until the harmonic analysis has been performed upon the records of the meson component at Uppsala, Kiruna, and Murchison Bay.

Acknowledgements. A grant from the foundation of Knut and Alice Wallenberg made it possible to carry on the work at Murchison Bay for another year after the end of the IGY-expedition.

We are especially indebted to Professor Gösta H. Liljequist the leader of the Swedish-Finnish-Swiss IGY-expedition, for the excellent facilities at Murchison Bay and for his interest in the cosmic ray enterprise. We thank him also for putting the meteorological records of the expedition at our disposal.

We also wish to thank Mr Karl-Erik Heikkilä who during the first year assisted one of us (E. Dyring) in the work at Murchison Bay and Mr Lars O. Andersson, who during the second year had the responsibility for the cosmic ray equipment. We are also indebted to the technician of the IGY-expedition, Mr Hans Engström, for valuable services. We thank him as well as everyone else who helped in securing the cosmic ray records.

References

Alfvén, H., 1954: On the origin of cosmic radiation, Tellus 6, p. 232.

Brunberg, E.Å., 1953: Experimental Determination of Electron Orbits in the Field of a Magnetic Dipole, Part I, Tellus 5, p. 135.

Brunberg, E.Å., 1956: Cosmic Rays in the Terrestrial Magnetic Dipole Field, Tellus 8, p. 215.

Brunberg, E.Å., 1958: The optics of cosmic ray telescopes, Arkiv f. Fys. 14, p. 195.

Brunberg, E.Å., and Dattner, A., 1953: Experimental Determination of Electron Orbits in the Field of a Magnetic Dipole, Part II, Tellus 5, p. 269.

Brunberg, E.Å., and Dattner, A., 1954: On the Interpretation of the Diurnal Variation of Cosmic Rays, Tellus 6, p. 73

Dattner, A., and Venkatesan, D., 1959: Anisotropies in Cosmic Radiation, Tellus 11, p. 239.

Dorman, L.I., 1957: Cosmic Ray Variations (Variatsii Kosmicheskikh Luchey) Translation prepared by Technical Documents Liaison Office, Wright-Patterson Air Force Base, Ohio.

Dyring, E., 1960: Statistical Studies of the Performance of Cosmic Ray Recording Instruments. In preparation.

Firor, J.W., Fonger, W.H., and Simpson, J.A.: Cosmic radiation intensity-time variations and their origin, V. The daily variation of intensity, Phys.Rev. 94, p. 1031.

Liljequist, G., 1959: Murchison Bay. Den svensk-finsk-schweiziska expeditionen till Nordostlandet 1957 - 58. Ymer 1959, p. 81.

Malmfors, K.G., 1945: Determination of Orbits in the Field of a Magnetic Dipole with Applications to the Theory of the Diurnal Variation of Cosmic Rays, Arkiv f. Matemat., Astron. och Fys. 32 A, Nr 8.

Pomerantz, M.A., Sandström, A.E., Potris, V.R., and Rose, D.C., 1960: Solar Disturbances and the Cosmic Ray Equator, Tellus, in manuscript.

Rothwell, P., 1958 a: Cosmic Rays in the Earth's Magnetic Field, Phil. Mag. 3, p. 961.

Sandström, A.E., 1955: On the Correlation between Geomagnetic Activity and the Diurnal Variation of Cosmic Rays, Tellus 7, p. 204.

Sandström, A.E., 1956: Experimental Evidence of the Directional Components of Cosmic Rays, Tellus 8, p. 18.

Sandström, A.E., 1958 a: Cosmic Ray Diurnal Variation and Geomagnetic Activity, Memoria del V Congreso Internacional de Radiacion Cosmica, Mexico, p. 340.

Sandström, A.E., 1958 b: The latitude effect of the cosmic ray nucleonic component in relation to the magnetic dip, Ark. Fys. 14, p. 409.

Sandström, A.E., and Lindgren, S., 1959: First and second harmonics of the daily variation of the cosmic ray nucleonic component at Uppsala Aug. 31, 1956 to Aug. 31, 1957, Ark. Fys. 16, p. 137.

Sekido, Y., and Kodama, M., 1952: Diurnal variation of vertical cosmic rays, Rep. of Ionosph. Research in Japan, 6, No 2.

Simpson, J.A., Fonger, W., and Treiman, S.B., 1953: Cosmic Radiation Intensity-Time Variation Method and Meteorological Factors. Phys. Rev. 90, p. 934.

Åström, E., 1956: Focusing of Paraxial Rays in a Magnetic Dipole Field, Tellus 8, p. 254.

Åström, E., 1958: Focusing of Paraxial Rays in a Magnetic Dipole Field, Memoria del V Congreso Internacional de Radiation Cosmica, Mexico, p. 332.